

ANALYTICAL STUDY OF THE EFFLUENTS FROM A HIGH TEMPERATURE ENTRAINED FLOW GASIFIER

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INTRODUCTION

The toxic and carcinogenic potentials of various coal conversion products and by-products have led to detailed studies of effluents including trace contaminants produced by coal gasifiers. A wide variety of coal gasification schemes have been proposed, and many are presently under development to meet the immediate and future demands for clean gaseous fuels.

High temperature entrained flow coal gasifiers have a well-known advantage over lower temperature fixed-bed or stirred-bed gasifiers. This advantage is the marked reduction in tars, phenols, and other condensible hydrocarbons as gasifier by-products. For example, the Lurgi fixed-bed gasifiers produce from 50-100 pounds of tar, 30-70 pounds of tar oil and naptha, and 8-12 pounds of phenols per ton of coal (1,2). Similar by-product compounds and yields have been reported for a fluidized bed gasifier operated by the Pittsburgh Energy Research Center (3). On the other hand, the Koppers-Totzek and Texaco High temperature entrained flow gasifiers are claimed to produce negligible amounts of tars or oils as by-products. The gas and water purification equipment is, therefore, less complicated and less expensive than that required for the Lurgi process. It was anticipated that advanced high temperature entrained flow gasifiers would also have this advantage.

The experimental gasifier studied in this report is a pressurized, entrained-flow gasifier that has a capacity of 100 pounds of coal per hour. This gasifier has a downflow configuration with some similarity to an entrained flow gasifier operated by the Bureau of Mines during the period 1952-1962. It also has some similarity to the Texaco-entrained flow gasifier configuration. Throughput rates of over 1,000 pounds of coal per hour per cubic foot of gasifier volume have been demonstrated with cold gas conversion efficiencies in excess of 75 percent.

A diagram of the laboratory gasifier and the necessary coal feeding, gas cooling and cleaning, and ash handling equipment is presented in Figure 1. Major equipment is noted in this figure.

Pulverized coal is fed to the gasifier from a pressurized feed hopper entrained in a stream of air or recycled product gas. The coal is rapidly mixed and reacted with a mixture of superheated steam and oxygen. The reaction is carried out at pressures of 50 to 300 psig and gasifier outlet temperatures 2300-2800°F. Residence times for gasification reactions are of the order of 0.1 second.

The gasifier products pass downward into a quench section where they are partially cooled by mixing with a feed stream of water and/or saturated steam or simply by heat transfer to monotube boiler coils which form the walls of this section. Sufficient cooling occurs in this section to solidify the molten ash droplets.

The products then pass into a slag removal section where the slag droplets and larger fly-ash particles are separated by gravity, dropping into the lower section of this vessel that is partially filled with water. The slag is periodically discharged through a lock hopper and transported to a settling pond. The gasification products then pass through a heat exchanger and into a scrubber column.

Cleaning of soot and fly-ash particles from the gas is accomplished in the water scrubber column. Unreacted steam is also condensed in this column. A recycle water stream is pumped through a heat exchanger to remove the heat of condensation, and a feed stream of cooled water is introduced at the top of this column to provide final cooling and washing, and to suppress foaming. Approximately six pounds of cooled water is required per pound of coal fed.

The overflow from the scrubber passes through a fabric filter to remove the solids and the filtered liquor is discharged through a pressure reduction valve into a flash tank where dissolved gases are released and separated from the water.

In this study, a detailed characterization of pollutants associated with the previously described gasifier has been performed.

EXPERIMENTAL

Samples were taken from the cooled and water-scrubbed product gas stream, the scrubber effluent water, the gas evolved on depressurization of the scrubber water, and the particulate matter filtered from the scrubber water during gasification of a high-volatile, non-caking, Utah bituminous coal. Four process parameters were varied; coal feed rate, reactor pressure, oxygen to coal ratio, and steam to coal ratio. The compositions of these samples were determined using the analytical techniques of gas chromatographic mass spectrometry, proton-induced x-ray emission spectroscopy, thermometric titrimetry, ion chromatography, and atomic absorption spectroscopy. The scrubber water analysis scheme is shown in Figure 2.

RESULTS AND DISCUSSION

The gasifier test matrix is given in Table 1. Individual runs were made under each set of conditions, and only one condition was varied in consecutive runs. The constituents found in the product gas, filtered scrubber water, organic extract of

Table 1. GASIFIER TEST MATRIX

Run Number	Coal Feed Rate (lbs. coal/hr.)	Reactor Pressure (PSIA)	Oxygen to Coal Ratio	Steam to Coal Ratio
1	40	150	0.9	0.1
2	40	150	0.9	0.3
3	40	150	0.9	0.5
4	40	150	0.8	0.3
5	40	150	1.0	0.3
6	40	300	0.9	0.3
7	40	75	0.9	0.3
8	20	150	0.9	0.3
9	60	150	0.9	0.3

particulate matter, and gas obtained during depressurization of the scrubber water are given in Tables 2 through 5. The variation from run to run was found to be insignificant and, therefore, the values reported are averages of all runs. These data emphasize the low levels of contamination produced by this particular gasifier. The comparison between the scrubber water and the uncontaminated water before entry

into the scrubber tank (Table 3) demonstrates the cleanliness of the gasifier operation. Even the organic compound levels are extremely low (Table 4). The presence of phthalates in the scrubber water is due to a ramming mix used in the reactor.

Table 2. PRODUCT GAS COMPOSITION

Species ^a	Average Volume Percent	Analytical Technique Used ^b
CO	42.4	GC
H ₂	31.2	GC
CO ₂	12.3	GC
N ₂	6.3	GC
CH ₄	7.2	GC
Average Concentration (ppm)		
H ₂ S	590	DT
H ₂ CN	1.7	DT

^aSO₂, COS, NH₃, CS₂ and hydrocarbon gases were not detected.

^bGC = Gas Chromatography, DT = Dräger Tube

Table 3. ANALYSIS OF FILTERED SCRUBBER WATER

Species	Average Concentration (ppm)		Analytical ^a Technique Used
	Before Scrubber	After Scrubber	
Elemental			
S	10.0	17.8	PIXE
Cl	19.2	18.4	PIXE
K	0.5	1.4	PIXE
Ca	28.7	75.4	PIXE
Fe	0.3	11.6	PIXE
Cu	0.2	0.2	PIXE
Zn	0.3	1.2	PIXE
Sr	0.0	1.0	PIXE
Inorganic			
F ⁻	0.1	1.4	IC
Cl ⁻	11.7	13.7	IC
NO ₂ ⁻	0.1	0.3	IT
SO ₃ ⁻	4.4	3.9	IC
NO ₃ ⁻	1.9	2.5	IC
SO ₄ ²⁻	41.4	43.4	IC
HCO ₃ ⁻	219.0	390.1	TT
Organic			
Tributylphosphate	0.0	2.7 × 10 ⁻³	GC
Dibutylphthalate	0.0	2.8 × 10 ⁻³	GC

^aPIXE = Proton-Induced X-Ray Emission Spectroscopy

IC = Ion Chromatography

TT = Thermometric Titrimetry

Table 4. GAS CHROMATOGRAPHIC ANALYSIS OF ORGANIC EXTRACT
OF PARTICULATE MATTER FROM SCRUBBER WATER

Compound ^a	Average Concentration ^b (expressed as ppb in scrubber water)
Naphthalene	25.0
1-Methylnaphthalene	1.4
2-Methylnaphthalene	1.3
Biphenyl	1.2
Acenaphthylene	5.8
Acenaphthene	5.3
Methylacenaphthylene	3.1
Phenanthrene	3.7
Fluoranthene	2.9
Pyrene	3.3
dibutylphthalate	6.1
diamylphthalate	7.0

^a A number of additional unidentified compounds were present in concentrations less than 0.5 ppb

^b All quantitation of organic compounds was done with respect to a naphthalene standard

Table 5. ANALYSIS OF GAS OBTAINED DURING DEPRESSURIZATION
OF SCRUBBER WATER

Species ^a	Average Concentration (expressed as ppm in scrubber water)	Analytical Technique Used ^b
CO	87.7	GC
H ₂	2.3	GC
CO ₂	160.1	GC
N ₂	80.5	GC
CH ₄	8.5	GC
H ₂ S	1.6	DT
H ₂ CN	0.02	DT
SO ₂	1.7	DT

^a COS, CS₂, NH₃ and hydrocarbon gases were not detected

^b GC = Gas Chromatography, DT = Dräger Tube

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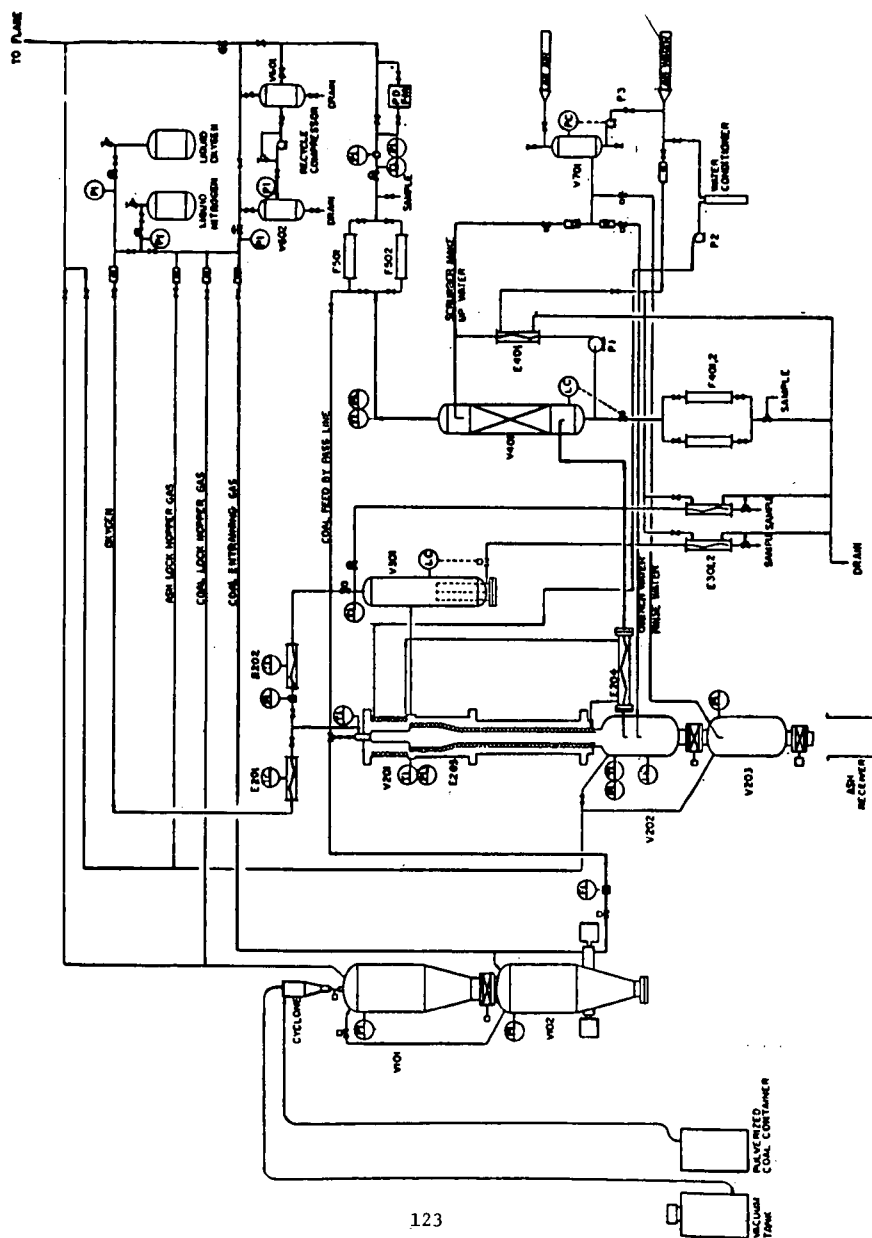


Figure 1. Flow diagram of Laboratory Scale Gasifier

SCRUBBER EFFLUENT LIQUOR

1. Bleed to atmospheric pressure.
2. Collect gas samples in lock syringes.
3. Filter through glass-fiber filter.

FILTRATE

PARTICULATE MATTER

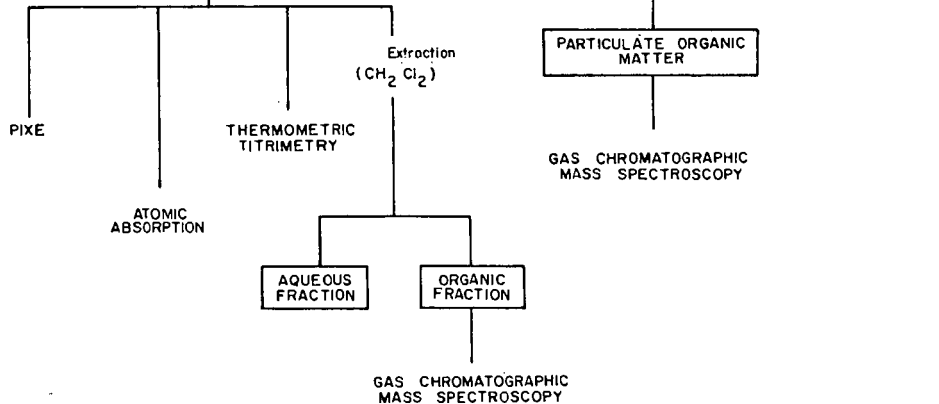


Figure 2. Scrubber water analysis flow diagram